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28SEP02 E751582-1 C20995
P01/7700 0.00-0222466.5

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

The Patent Office

Cardiff Road
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1. Your reference WATERFILLROTOR

2. Patent application number 0222466.5 27 SEP 2002

3. Full name, address and postcode of the or of each applicant *(underline all surnames)*
Marine Current Turbines Limited
The Manor House,
Chineham Court,
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Patents ADP number *(if you know it)* 8083990002

If the applicant is a corporate body, give the country/state of its incorporation
A British Body Corporate

4. Title of the invention IMPROVEMENTS IN ROTOR BLADES AND/OR HYDROFOILS

5. Name of your agent *(if you have one)*
Patrick Russell-Rayner,

"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*
Business Centre West,
Avenue One,
Business Park,
Letchworth Garden City,
Hertfordshire
SG6 2HB

Patents ADP number *(if you know it)* 7488984001

6. If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number

Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*

7. If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application

Number of earlier application	Date of filing *(day / month / year)*

8. Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:*
a) any applicant named in part 3 is not an inventor, or
b) there is an inventor who is not named as an applicant, or
c) any named applicant is a corporate body.
See note (d))

Yes

Patents Form 1/77

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Continuation sheets of this form	NONE
Description	ELEVEN PAGES
Claim(s)	NONE
Abstract	NONE
Drawing(s)	THREE SHEETS +3 RM

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature

P. Russell-Rayner

Date 25/09/2002

12. Name and daytime telephone number of person to contact in the United Kingdom: Pat Russell-Rayner 01462 672538

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IMPROVEMENTS IN ROTOR BLADES AND/OR HYDROFOILS

BACKGROUND OF THE INVENTION

This invention relates to improvements in rotor blades and/or hydrofoils particularly as applied to water current turbines and other water current kinetic extractors..

In particular the present invention relates to turbines and other such devices capable of interacting with a flow of fluid in such a manner as to transfer energy from the fluid to a mechanical device.

More particulalrly the present invention relates to turbines or other devices arranged to be driven by the acton of a flow of water or other liquid medium.

Thus the presnt invention relates in particular to the use of turbines and similar moving devices for extracting kinectic energy from flowing water for the purposes of utilising such kinectic energy to produce either electricity or shft power for utilisation for a required purpose.

Flowing water (which may be either fresh or sea water) used in the context of this invention is a characteristic of tidal, marine, esturial or river currents.

THE PRIOR ART

It is known how to use turbines for such purposes. For example in our British Patents GB22560022B and GB2311566B and also in our British Patent Application 2348250 we have disclosed constructions pertaining to water drivable turbines, i.e., rotors supported with the water column of the sea, river or an estuary so that the flow of water may turn the rotor to produce either shaft power or electricity for utilisation for a required purpose. Various alternative.

concepts have been proposed by others.

FURTHER BACKGROUND OF THE INVENTION

When a turbine is used in such a way that it is driven by a flow of water the extraction of energy from the flow causes reactive forces that need to be counteracted by some form of fixed or floating and anchored structure. Hence the rotor or any other moving element of such a turbine will be held in place within the water column by a fixed structure in such a manner that it delivers usable power through a rotating shaft.

In most cases the mechanism for extracting energy from the flow will consist of lift surfaces in the form of hydrofoils rotating in the manner of an axial flow turbine but in some cases devices may be applied which oscillate or reciprocate as a result of interaction with the passing flow and in such a case they may deliver an oscillating force in some manner other than via a rotating shaft, such as, for example, through hydraulic or pneumatic cylinders or through any other appropriate mechanism capable of converting said reciprocating motion into some convenient form for the transmission of power to a device capable of usefully applying it. The concepts of the present invention are applicable devices whether or not such devices comprise rotating turbines or oscillating hydrofoil apparatus capable of extracting energy from flowing water currents.

The need for the proposals of the present invention arises as a result of variation in static pressure experienced by any vertical movement through a water column. It is well known that the static pressure in a column of water will increase by approximately 1 (one) bar for every 10 metres extra depth as a result of the density of water; i.e. the static pressure at a depth of lOm below the surface will be approximately 1 bar, at a depth of 20m it will be approximately 2 bar and so on. As a result of this, any sizeable turbine will experience variations of static pressure if its active components move through a vertical height;. Thus in the case

of a turbine rotor of 2Om diameter the rotor will experience a static pressure variation of approximately 2 bar between the top edge of the rotor and the bottom edge of the rotor assuming said rotor is mounted with its rotational axis horizontal so as to effectively face the flow of water to most effectively extract energy from the water flow.

As a result the rotating rotor blades will be exposed to cyclic pressure variations. In the 20m diameter example, each rotor blade will experience, on average, approximately plus or minus 1 bar variation between the position when a rotor blade is at the uppermost point of rotation compared with one at the lowermost point of rotation, assuming the middle of each blade (i.e. halfway between the axis of rotation and the tip of the blade) as a reference point. This same phenomenon will apply to any reciprocating device which moves in a vertical plane through the water column; for example a horizontal hydrofoil device that moves up and down will experience a static pressure variation of approximately 1 bar for each 10m of vertical movement in the water column.

In most cases the rotor blades or foils are hollow, as is preferred for any sizeable structure, because clearly a solid rotor blade would tend to be unacceptably heavy with a large rotor. In such cases the static pressure variations that will apply when the rotor blade or foil either rotates in a vertical plane in the water column or oscillates vertically will tend to manifest themselves as a pressure difference between the interior void of the rotor blade or foil and the external fluid. If the rotor blade or foil is effectively a sealed container, then the cyclic pressure difference between the interior and exterior of said container will manifest itself as a large cyclic force seeking to effectively make the blade or foil surface "breath"; i.e. when the foil or blade is in a low position in the water column it will tend to be compressed by the external fluid and when it rises the reducing pressure will tend to make it seek to expand. Since the resulting force will be a function of the surface area multiplied by the pressure difference it can manifest itself as a very large and frequently recurring load on the surface of the rotor blade

or foil which presents the designer with some serious difficulties in terms of the need to avoid failure by cyclic stress fatigue of the material.

Filling the void in any rotor blade or hydrofoil with lightweight material (e.g. foamed plastic) that is not easily compressible could be perceived as a solution to this problem, but the probability is that the surface of the rotor-blade or hydrofoil will flex under the influence of the cyclic static pressure variations and will therefore suffer from fatigue loadings combined with a risk of failure in the event that the surface material of the rotor blade of hydrofoil ceases to be bonded securely to the internal filler, de-laminates and hence creates a void.

OBJECTS OF THE INVENTION

It is an object of the present invention to provide rotor blades or foils suitable for devices capable of extracting energy from a moving water column, whether the device rotates as in the case of an axial flow turbine or whether it reciprocates in the flow.

A further object of the present invention to provide improved rotor blades or hydrofoils for turbine rotors or reciprocating foils which function by moving within the water column of flowing currents the purpose of extracting energy, whether they be at sea, in rivers or in estuaries.

A further object of the invention is intended to provide a rotor of hydrofoil construction that serves to mitigate or reduce the structural problems that are likely as a result of static pressure variations which would tend to cause any sealed and hollow rotor blade to seek to "breathe" (i.e. expand and compress) under the influence of cyclic pressure variations caused by vertical movements in the water column.

STATEMENTS OF THE INVENTION

According to the invention there is provided a method of counteracting the effects of variation in static pressure upon a hollow rotor blade or hydrofoil immersed in the column of flowing water by equalising the pressure inside and outside the rotor blade or hydrofoil.

Preferably, the pressure is equalised by filling any voids in the rotor blade or hydrofoil with a liquid.

Preferably, the pressure equalisation is controlled by means of pressure balancing control means provided upon the rotor blade or hydrofoil.

Conveniently, the pressure control is effected by means of a diaphragm or piston arrangement and are not intended to restrict the application to illustration of the details for implementing such a design.

According a further aspect of the invention there is provided a method for filling the voids in the rotor blades or hydrofoils for devices capable of extracting energy from a moving water column, whether the device rotates as in the case of an axial flow turbine or whether it reciprocates in the flow whereby cyclic static pressure fluctuations caused by vertical movement of the rotor blades or hydrofoils through the water column do not cause large fluctuating stresses as a result of air-filled or gas-filled voids allowing the external surface of said rotor blades or hydrofoils to "breathe"; i.e. to expand and contract under the influence of external static pressure variations..

According to a still further aspect of the invention the interior of a hollow rotor blade or hydrofoil is flooded with liquid in such a way that it is not possible for a void to form which can allow the aforementioned "breathing" effect when the rotor blade moves cyclically through a vertical distance in the water column.

Thus according to the method of the invention 'breathing' effect in voids in the interior of a hollow rotor bale or hydrofoil is prevented or offset by of filling the interior of the rotor blade or hydrofoil with liquid in such a way that it is not possible for a void to form which can allow the aforementioned "breathing" effect when the rotor blade moves cyclically through a vertical distance in the water column.

In a preferred method voids within a rotor blade or hydrofoil are filled with water or other substantially incompressible liquid, the arrangement being such that potential for the casing or outer surface of the hydrofoil or rotor blade to suffer undesired stresses and strains as a result of the aforementioned 'breathing' effect will be significantly reduced.

Conveniently rotor blades or hydrofoils for the purposes of the filling of water (or whatever liquid the rotor or hydrofoil interacts with) are provided openings at the extremities thereof thereby to allow air to be displaced when the rotor or hydrofoil is submerged.

Conveniently the interior of said rotor blade or hydrofoil can be treated with anti-fouling and/or anti-corrosive coatings to prevent internal marine growth, bio-fouling and/or corrosion. Conversely, if the rotor blade or hydrofoil is lifted out of the water for maintenance or some other purpose, then the water inside it will be free to drain out of the openings provided.

Preferably, such openings in a rotor blade or hydrofoil may be closed with a diaphragm or a piston in a cylinder arrangement to equalise the pressure of an internal fluid filling the internal voids relative to the external fluid. With such an arrangement, separate filling and draining orifices will be provided with provision for said orifices to be closed with suitable plugs or caps to contain the internal fluid and prevent ingress of the external fluid.

In accordance with the present invention techniques are provided for avoiding the development of a significant fluctuating force between the exterior and interior of hydrofoils or rotor blades that are required to move vertically in a cyclic manner within the water column.

BRIEF DESCRIPTION OF THE DRAWINGS

For a better understanding of the invention and to show how to carry the same into effect reference will now be made to the accompanying drawings in which:-
Figure 1: schematically illustrates pressure variation and its effect on a rotor blade moving vertically within the liquid column;

Figure 2: illustrates a flooded rotor blade with orifices near the blade root and at its tip, the orifices being designed to allow the rotor blade to flood easily and to drain its contents when removed from the water; and

Figures 3A and 3B respectively are schematic sectional views of a diaphragm and a piston arrangement which will equalise the internal and external pressure while maintaining separation between the external working fluid and the internal filling fluid

DESCRIPTION OF PREFERRED EMBODIMENTS

Referring now to Figure 1 rotor blades or hydrofoils represent the interactive components of a water current kinetic energy converter in taking energy from moving water as a transmitted force that can be harnessed, but they can experience static pressure variation as a result of the vertical movement they undergo in the water column. These pressure variations will be cyclic and the forces incurred by the surface material of any hydrofoil or rotor blade will be

large since they are a function of both the surface area of the rotor blade and the surface pressure variation.

The left hand side of the composite Figure provides a front view of a two bladed axial flow rotor. The static pressure on the rotor blade fluctuates as the rotor turns. In the Figure 1 the right hand part thereof shows in schematic form on a turbine mounted from a support upstanding from the seabed. In the Figure the turbine is illustrated in side view. Arrows at various levels respectively indicate, moving down from water level, variation in water static pressures. In particular the upper most arrow illustrates static pressure at the tip of the upper blade and the next arrow indicates the mean pressure at the centre of the upper blade. A further arrow indicates the pressure at the axis of rotation of the rotor, a further arrow indicates mean pressure at the centre of the lower blade whilst the remaining arrow indicates the static pressure at the tip of the bottom blade.

For example, in relation to pressures on a rotor blade a pressure variation of 1 bar (caused by a vertical static pressure variation of just 10m) will cause a force of approximately 100kN per square meter, which is the equivalent of a 10 tonne force acting on each square meter of the surface.

It will be appreciated that the present invention offers arrangements techniques for avoiding the development of a significant fluctuating force between the exterior and interior of hydrofoils or rotor blades that are required to move vertically in a cyclic manner within a water column. It has been found/appreciated that if this result is achieved, then the surfaces of the foils or rotor blades need carry no more load than that which will be generated through the process of transmitting lift forces from the fluid into the structure of the rotor or the energy extracting device. In practice, the action of reducing the loads on such components allows the design thereof to be simplified and additionally enables a reduction in the in-strength requirements for the blades which in turn offers

cost-advantages. It may also offer further advantages in extending the fatigue life of the rotor blades or hydrofoils.

Thus according to the invention basic principle of this invention is to flood the interior of the rotor blade or foils with liquid in such a way that it is not possible for a void to form which can allow the aforementioned "breathing" effect when the rotor blade moves cyclically through a vertical distance in the water column.

Replacing an air-filled interior with liquid improves the situation since liquids are relatively incompressible, however unless the liquid is pressurised it may allow a vacuum or low pressure void to form which could impose both high stresses and high strains on the surface material of the foil or rotor blade. Therefore the first solution is to fill the blade with a liquid pressurised to a pressure similar to the mean pressure at the operating depth in the water column, as indicated in Figure 2. It will be understood that steps would be taken to ensure that the liquid is as free as appropriate of dissolved gasses or impurities that could come out of solution and cause a void to form.

Referring to Figure 2, from the enlarged schematic view of a rotor blade it can be seen that in the case of a two-bladed axial flow rotor (as illustrated) there can be voids (4) within the envelope or surface casing of the rotor blades. The rotor blades (1) also contain a spar or structural member (2) surrounded by a shaped casing or skin (3) which gives the correct profile or shape for efficient development of the lift forces necessary to extract energy from the passing fluid. The voids between the casing and the main spar may be connected by structural ribs or other components not illustrated, but for the purpose of this invention they will be open or perforated so as to allow the passage of fluid throughout the rotor blade void. Orifices are provided at the root (5a) and at the tip of the rotor blade (5b) to permit water (or the liquid the system operates in) to flood into the void and to permit air trapped within it to escape. These orifices in the rotor blade or

foil will effectively allow the water (or whatever fluid) to fill the voids (4) when the rotor is first submerged and conversely they will allow the liquid to drain out when it is lifted above the surface.

In practice when using devices of this kind either in the sea or in river and estuarial situations, there may be a problem with marine biological growth inside the flooded void. Two alternative means are proposed for mitigating or preventing this problem; either appropriate anti-fouling internal finishes are to be used to inhibit any such growth from taking place, or the open orifices are to be replaced by a diaphragm or a piston arrangement (see Figure 3) which will equalise the internal and external pressure while maintaining separation between the external working fluid and the internal filling fluid. The internal fluid when diaphragms or pistons are used to contain it would also probably but not necessarily be water (in the case of a water turbine) but if water is to be used it would be dosed with inhibitor to prevent any undesirable bio-activity and also to mitigate against any corrosion.

Figure 3A shows a schematic arrangement for both a diaphragm pressure equaliser and Figure 3B a piston pressure equaliser. In the example of the diaphragm pressure equaliser, the outer casing or envelope of the rotor blade (1) has an orifice (2) cut into it. A flexible diaphragm which may be made from elastomeric material (3) is clamped to the inside surface of the envelope by a ring (4) which may be fixed with bolts (as illustrated) or by some other means such as clamps. When a pressure differential occurs between the external and internal sides of the rotor blade envelope or casing it will cause a minor movement of the diaphragm which due to the high bulk modulus of water will only need to move a small amount to equalise the pressure; i.e. the diaphragm will tend to keep the liquid sealed inside the rotor blade at a similar instantaneous static pressure as that of the orifice (2). This is just one example of how a diaphragm might be arranged; other configurations may also be possible to achieve the same objective.

In the example of a piston-based pressure equaliser (Figure 3B), the outer envelope or casing of the rotor blade (1) has an orifice (2) which connects via a short length of pipe (8) to a cylinder (5). The cylinder (5) contains a piston (6) constrained towards the centre of the axial length of the cylinder by springs (7) arranged on each side of the piston. The piston is a close fit within the cylinder and is fitted with seals to prevent leakage. Any variation in static pressure at the orifice (2) will tend to move the piston a small amount until it effectively causes the pressure on each side of the piston to be equalised, thereby adjusting the pressure in the interior of the blade to be close to that externally. This is just one example of how a cylinder and piston might be arranged; other configurations may also be possible to achieve the same objective.

The figures provided with this patent application are intended to illustrate the concept of equalising the pressure inside and outside the rotor blade or hydrofoil with a diaphragm or piston arrangement and are not intended to restrict the application to illustration of the details for implementing such a design.

When the rotor blade or hydrofoil is to be filled with a liquid as just described, means will be provided both for draining the liquid in order to lighten the rotor blade or foil for transport and when installing it and for refilling the internal voids with liquid prior to operating the system. An important aspect is to no air or other gas is trapped within the rotor blade or hydrofoil so provision for bleeding off any trapped air or other gas is an essential requirement in the event that the filling and draining holes do not adequately serve the purpose.

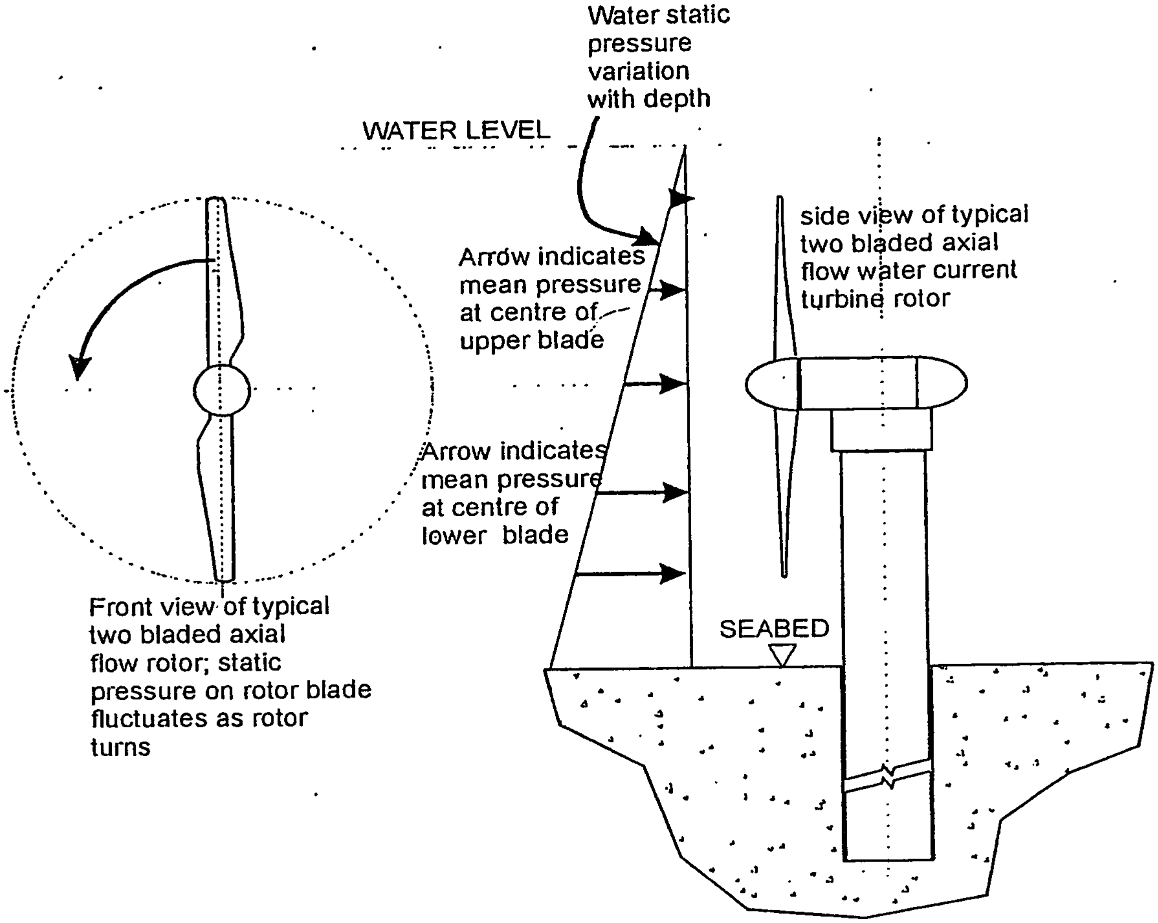

Water static
pressure
variation
with depth
WATER LEVEL
side view of typical
two bladed axial
flow water current
turbine rotor
Arrow indicates
mean pressure
at centre of
upper blade
Arrow indicates
mean pressure
at centre of
lower blade
SEABED
Front view of typical
two bladed axial
flow rotor; static
pressure on rotor blade
fluctuates as rotor
turns

FIGURE 1

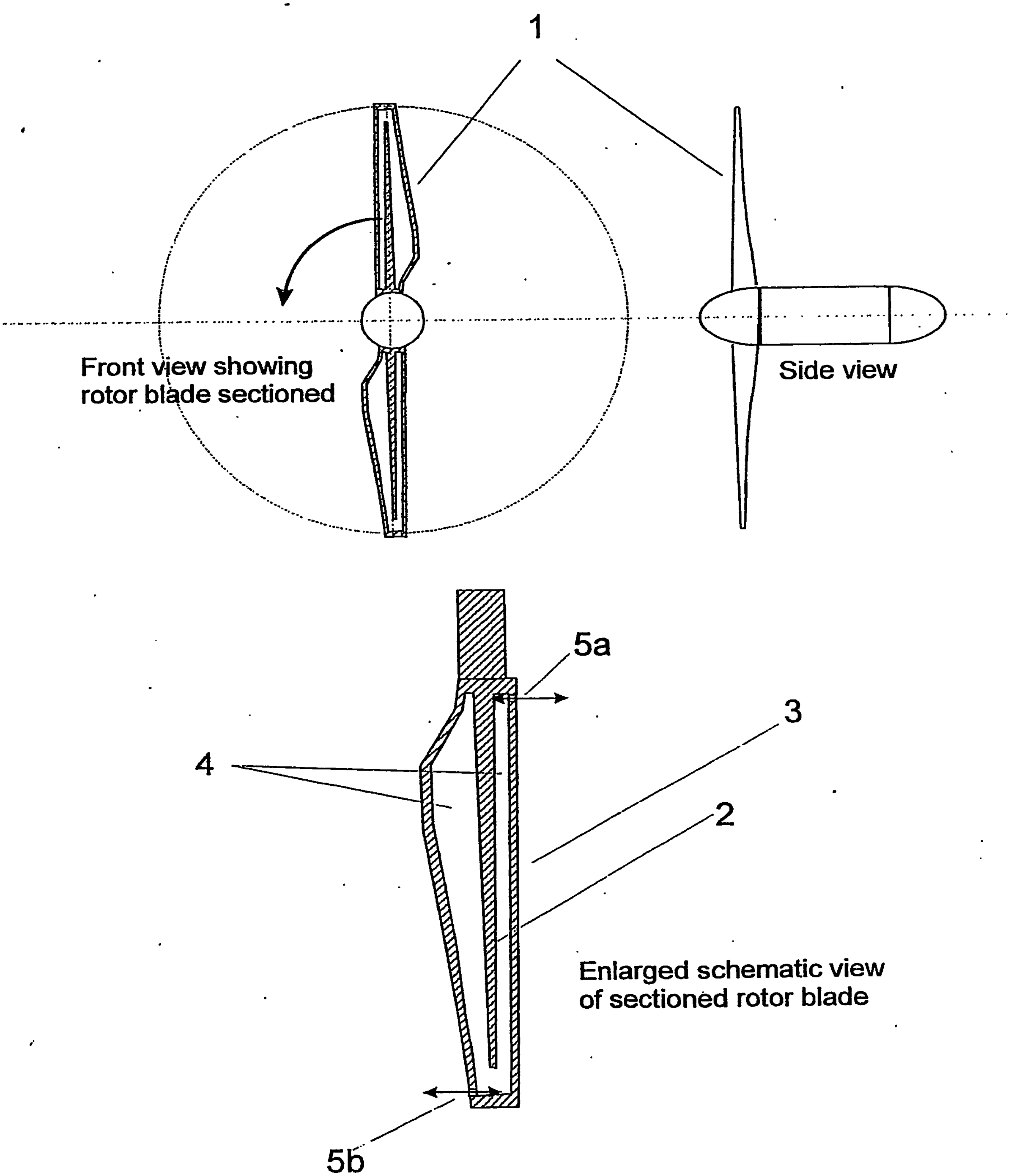
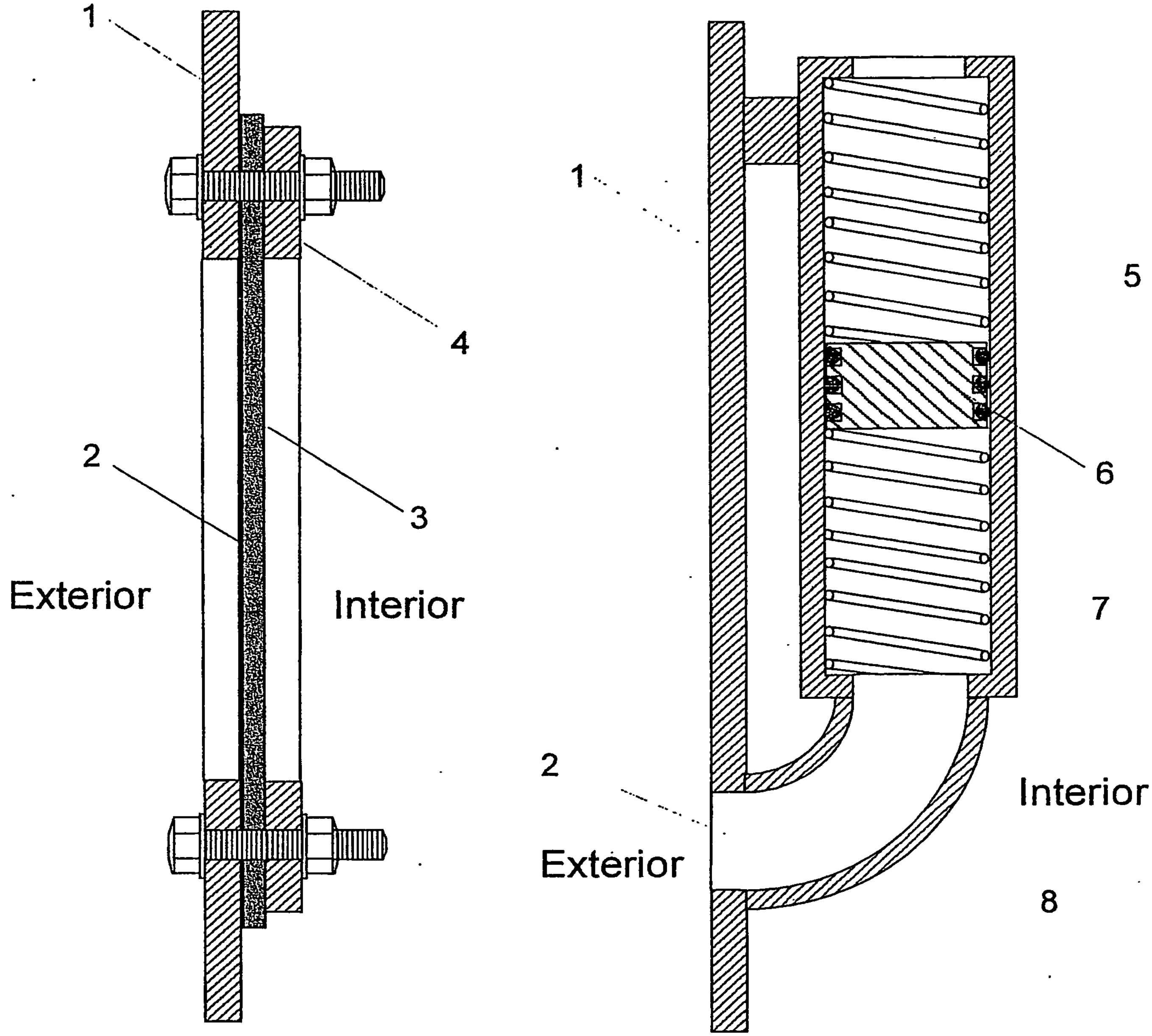

1
Front view showing
rotor blade sectioned
Side view
5a
3
4
2
Enlarged schematic view
of sectioned rotor blade
5b

FIGURE 2



A) schematic view of sectioned diaphragm pressure equaliser

B) schematic view of sectioned piston type pressure equaliser

FIGURE 3